Characterization and Application of Rice Husk for Removal of Heavy Metals from Laboratory Prepared Waste Water

A Thesis Submitted in Partial Fulfilment of

the Requirements for the degree of

Bachelor of Technology

in Civil Engineering

By

Trupti Sethi

Roll No-110ce0057

Under The Guidance of

Prof. K.K.Paul

Department of Civil Engineering

National Institute of Technology Rourkela

Rourkela-769008, Odisha, India

May, 2014

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NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA – 769008, ORISSA
INDIA

This is to certify that the thesis entitled "**Characterization and Application of Rice Husk for Removal of Heavy Metals from Laboratory Prepared Waste Water**" submitted by Trupti Sethi, Roll No. 110ce0057 in partial fulfilment of the requirements for the award of Bachelor of Technology degree in Civil Engineering at National Institute of Technology, Rourkela is an authentic work carried out by her under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

Date: May 10,2014

Place: Rourkela

Prof. K.K.Paul

Dept of Civil Engineering

National Institute of Technology,

Rourkela 769008

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Trupti Sethi

CONTENTS

ABSRACT

In this thesis work, adsorption technique has been applied for the removal of heavy metals such as Cu, Zn and Pb from water is rice husk. Rice husk is preferred to any other materials because of its abundant availability in India since rice production in India is very high and it's cost is quite lower than other materials. It is a highly efficient adsorption material that show nearly 95- 100% removal of heavy metals from water. Rice husk is prepared into two types of adsorbents in this study, the first one is obtained by grounding the rice husk into small particles of size less than 355µm and the second one is prepared by burning the clean rice husk in muffle furnace and treating it with citric acid. The waste water is prepared synthetically in the laboratory by taking 1ppm to 20 ppm concentrations of metal solutions. The prepared water is treated against two adsorbents with controlled temperature, pH, and initial concentration of metals. One gram of adsorbent material is taken for each 100ml of prepared water; the solution is then stirred continuously for 24 hours at a speed of 250 rpm at 40 degree temperature. The results obtained from the experiment are recorded and graphs are plotted to study the behavior of the adsorbent material in removing heavy metals from the water. The results obtained as the removal efficiency of grounded rice husk for Zn, Pb and Cu are 99.09%, 97.52% and 93.36 %, respectively. The removal efficiency of carbonized rice husk for Pb, Cu and Zn are found to be 96.45%, 96.31% and 96.64%, respectively. With the increase in duration of stirring action, the removal efficiency of the adsorbent material increases. From the performed experiments, removal of Zn from 5ppm solution of Zn for 0.5,1,2,3,5,18 hours are 82.37%, 88.32%, 90.51%, 92.48%, 93.98% and 97.19%, respectively.

Keywords

Adsorbent, carbonized rice husk, effluent treatment, grounded rice husk, heavy metals, waste water.

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Chapter-1

Introduction

INTRODUCTION

Heavy metals in water are originated from waste water of many industries. These heavy metals have hazardous effects on environment and human health. A little exposure to these heavy metals even at low concentration can cause many serious diseases (Kumar et al., 2012; Marin et al, 2010). So, the removal of heavy metals from water is to be considered seriously. Many techniques are adopted for decontamination of heavy metals from water. These methods include chemical precipitation, adsorption by activated carbon, member separation methods, coagulation, etc (Matheickal and Yu, 1999; Juang and Shiau, 2000; Lacour et al., 2001; Yan and Viraraghavan, 2001). The main disadvantage of these methods is high cost, low efficiency, labor intense operations, lack of selectivity. Therefore new methods are developed for decontamination of heavy metals from water (Gaballah and Kilbertus, 1998; Lee et al., 1998). So there is an urgency of finding new technique which will be effective to remove heavy metals from water. The new technique is of low cost, abundant in nature, has high potential for removal of heavy metals (Marshall et al., 1999; Wafwoyo et al., 1999; Vaughanet al., 2001). The adsorbents used in this method are basically inexpensive sorbent material obtained from agricultural waste materials or from the by-products of other industries. The adsorbent material used for this project work is rice husk, as they are easily available in India, has great surface characteristics, posses a lot of free electrons, carbon, silica and hydrogen ions, which makes it a good adsorbent of heavy metals (Boota et al., 2009; Lasheen et al., 2012; Osman et al., 2010). The rice husk is cleaned with de-ionized water then treated as per requirement to prepare them for treatment of laboratory prepared water contaminated with heavy metals. Two types of adsorbent material are prepared from the rice husk. The first adsorbent material is made by grounding the clean dry rice husk and sieving it, to obtain particle size less than 355µm. The small size particles give the greater surface area than the bigger size particles. Since the free electrons or hydrogen ions are highly present on the surface of the material and we know adsorption is a surface phenomenon, by increasing the surface area of the adsorbent material the efficiency of decontamination of heavy metals from water increase. The first adsorbent material is named as grounded rice husk (GRH). The second adsorbent material is prepared by burning the clean dry rice husk in muffle furnace at 500 degree temperature for 3 hours and then soaking it in 6M citric acid solution for 2 hours at 20 degree temperature, it is then further cleaned with distilled water and then dried. The second adsorbent is named as carbonized rice husk. The rick husk is burned and treated with citric acid to modify the carbon and silica contain in the material. The silica reduces the turbidity of water and activated carbon binds the non-polar materials while the polar materials remain in the solution. The waste water is prepared synthetically in the laboratory by taking 1ppm to 20ppm solutions of heavy metals of Cu, Zn and Pb. Then a definite amount 1-2 grams of adsorbent material is taken for each 100ml solution of heavy metals and stirred continuously for 24 hours in an electromagnetic stirrer. The experiment is carried out under certain optimize conditions, those are the temperature is made constant at

40 degree centigrade throughout the experiment, the solution of heavy metals with adsorbent added to it is stirred continuously for 24 hours at a constant speed of 250rpm, with constant pH. Then the time of stirring, pH of the solution and initial concentration of metals in the solutions is varied to study the behavior of the adsorbents under these specific conditions. The data and results of the experiment is observed and recorded for each adsorbents, graphs are plotted between respective parameters to show the behavior and efficiency for removal of heavy metals from water.

OBJECTIVES OF THE STUDY

- To determine the chemical composition of rice husks.
- To establish optimized conditions and potentiality of rice husks for removing Cu (II), Zn (II), and Pb (II) ions from synthetically prepared effluent.
- To study the effects of pH, time and initial concentration of metals on Cu (II), Zn (II) and Pb (II) adsorption.
- To predict removal efficiency of rice husk.

LITERATURE REVIEW

The rice husk has high potential for removal of heavy metals like Cu, Zn, Pb in terms of its adsorption capacity, binding mechanisms, experimental conditions and pretreatment methods (Okoro & Okoro, 2011). The survey shows that the rice husk has an equal or even greater adsorption capacity compared to other conventional adsorbents. In future it is expected to replace the traditional adsorbents used for decontaminating heavy metals from water as it has great advantages such as high efficiency even with low metal concentrations, low cost, no additional nutrients requirements, and easy operation (Boota et al., 2009; Lasheen et al., 2012; Osman et al.,2010).

The main advantage of rice husk over other conventional methods is its strong affinity and high selectivity towards heavy metals; this is because of the presence of binding groups on its surface (Banerjee et al., 2010). It is of low coast because of being generated from agricultural waste; this can be easily processed, applied and recovered without any adverse impact on the environment. It is eco friendly and innovative, sustainable waste management.

The adsorption process of heavy metals from waste water is influenced by various physical and chemical parameters like pH, temperature, initial heavy metal concentration, amount of adsorbent, particle size of adsorbents etc. These parameters determine the overall adsorption through affecting the selectivity and amount of heavy metals removed.

Among process parameters, pH has a significant role in controlling the adsorption of heavy metals. pH values can affect the surface charge of rice husk, the degree of ionization and speciation of heavy metals, the competition of the metal ions with coexisting ions in solution (Park et al., 2010).As the pH of the solution increases, the adsorption capacity of rice husk changes, removal of cationic metals increases, whereas that of anionic metals decreases. At lower pH, the overall surface charge of rice husk will be positive. The H^+ ions compete effectively with the metal cations causing a decrease in adsorption capacity. When pH values increase, the rice husk surface becomes increasingly negatively charged which favours the metal ions uptake due to electrostatic interaction. At very high pH, the adsorption stops and the hydroxide precipitation starts (El-Sayed et al., 2011; Njoku et al., 2011; Taha et al., 2011).

Heavy metal ions can transport from the solution to the surface of adsorbent owing to a driving force made by the initial metal concentration in the solution (Sahmoune et al.,2011; Taha et al., 2011). It is found that maximum adsorption capacity of rice husk increases with increase in initial metal concentration in the solution.

Time also has great impact on the adsorption capacity of the rice husk. With increase in time or duration of treatment of solution, the adsorption capacity increases. After 48 hours, there is only a negligible amount of heavy metal is found in the solution.

CHAPTER-2

METHODS ADOPTED

METHODS ADOPTED
Reagents and Samples

Sample-1: Grounded rice husk

Rice husk shown in is obtained from rice mills. To prepare the powdered husks, they are initially ground and homogenised using a food blender with steel blades for 10 min. Particle sizes <355µm were obtained by passing the milled material through a steel sieve shown in fig.1. Afterwards, the ground husks are stored in polyethylene bottles (high density) and used without any other physical or chemical treatment. The experiments are to be carried out in conical flask. (C.R. Teixeira Tarley,M.A. Zezzi Arruda, Biosorption of heavy metals using rice milling by-products, Chemosphere, 54(2004): pp.988)

The wastewater used is prepared synthetically in laboratory by taking 100ml solution of Cu, Pb, Zn with varying concentration from 1ppm to 20ppm and, finally, solutions of metals used for calibration procedures in atomic absorption spectrometry.

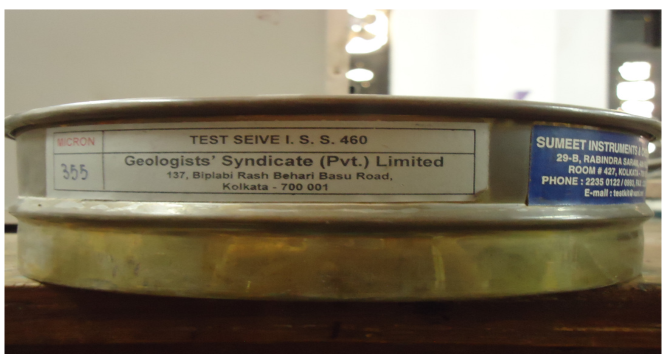

Fig.1 :355 µm sieve, used for sieving sample(powdered rice husk)

Sample-2: Carbonized rice husk

Rice husk was washed 3-4 times with de-ionized water to remove all dirt in its original particle size followed by filtration and were oven dried at 100°C. The cleaned and dried rice husk was then kept inside the muffle furnace (shown in fig.2) at 500°C for 3 hours. The burned rice husks were soaked in 0.6M of citric acid for two hours at 20 degree temperature. The acid slurry is then oven dried at 50 degree and then the product was cleaned and dried and used without any other further treatment (I Nhapi, N Banadda, R Murenzi et.al., Removal of Heavy Metals from Industrial Wastewater Using Rice Husks, The Open Environmental Engineering Journal, 2011, 4: pp 172). It is called Carbonized Rice Husks (CRH) shown in fig.3.

Fig2: Muffle Furnace


Fig3: Rice husk after treatment

Procedure to remove heavy metals from laboratory effluent

For these experiments 100 ml of a solution containing Cu(II), Zn(II), and Pb(II) at 1ppm to 20ppm concentrations is to be added with the adsorbent and stirred continuously at 250 rpm speed in a electromagnetic stirrer (shown in fig.5) for 24 hours at 40 degree constant temperature. Then the sample is allowed for settlement till clear water is seen on the surface, the sample the filtered and final concentration of metals is measured from the analysis using a Perkin-Elmer Model Analyst 200 atomic adsorption spectrometer shown in fig.4. The experimental parameters affecting the bioaccumulation of Cu (II), Zn and Pb (II) species are examined. The effect of pH on the ability of rice husks to adsorb metal ions was investigated. For this purpose, the pH values of the Cu (II), Zn and Pb (II) solution are varied from 2 to 6. In order to evaluate the treatment efficiency for other metals, after establishing the optimal conditions for Cu, Zn and Pb(II) laboratory effluent treatment. Thus, the initial and final concentrations of these metals are also determined, and the results are recorded.

Fig.4: Perkin-Elmer Model Analyst 200 atomic adsorption spectrometer.

Fig5: Electro-magnetic stirrer.

CHAPTER-3

CHARACTERIZATION OF RICE HUSK

OBSERVATION

Study of its chemical composition, morphological characteristic

- **Sample-1 (Grounded rice husk):**

Rice husk characterisation

The morphological characteristics of rice husks are evaluated by using a Scanning electron microscope shown in fig.6. The rice husk samples are covered with a thin layer of gold and an electron acceleration voltage of 20 kV was applied.

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Fig.6: Scanning electron microscope.

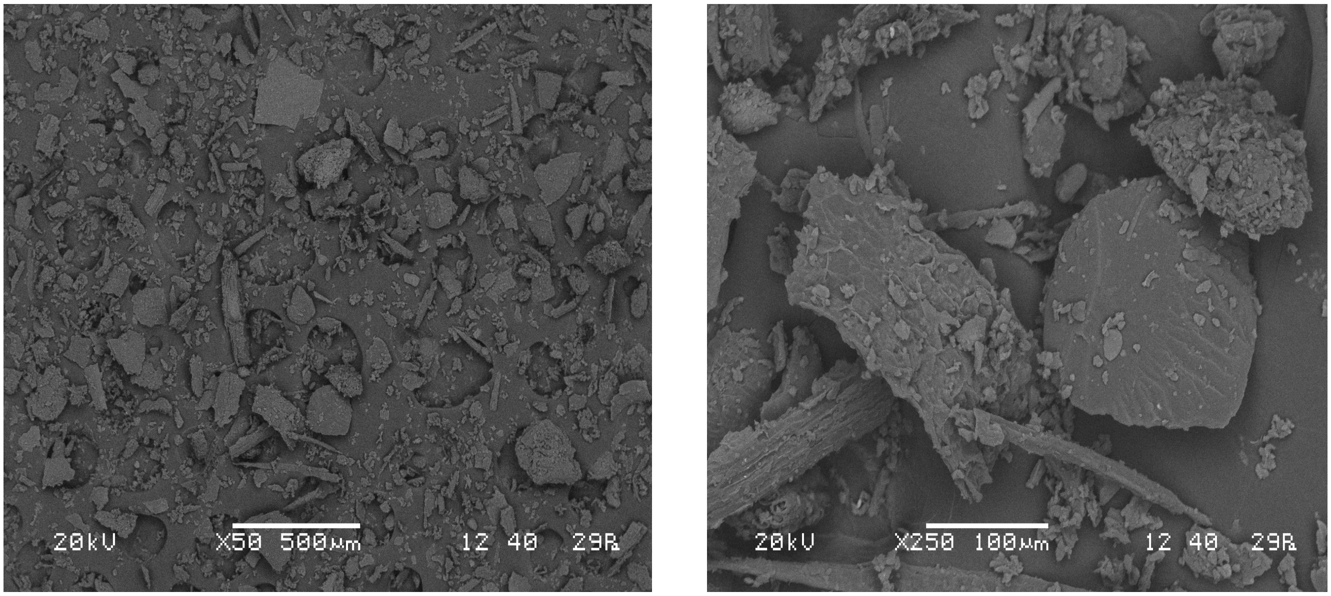


Fig.7:Scanning electron micrograph of rice husks (6355 lm) with (a) 100 and (b) 500 times of magnification.

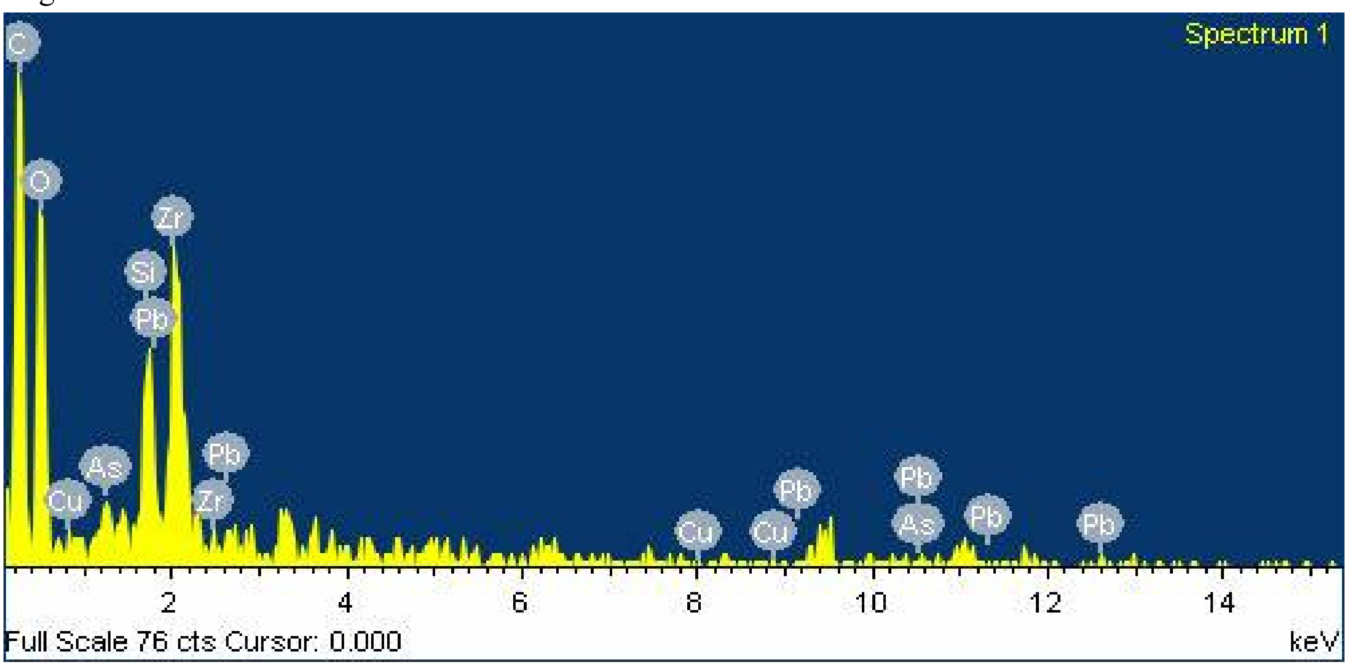
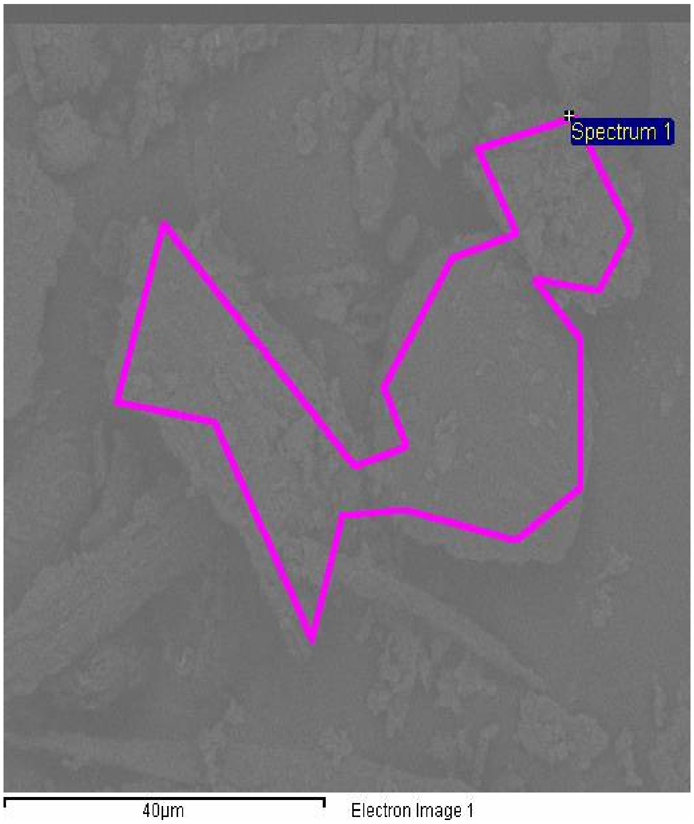


Fig.8(a): X-ray fluorescence spectrum of rice husks.



Spectrum processing :
No peaks omitted

Processing option : All elements analyzed (Normalised)
Number of iterations = 5

Standard :
C CaCO3 1-Jun-1999 12:00 AM
O SiO2 1-Jun-1999 12:00 AM
Si SiO2 1-Jun-1999 12:00 AM
Cu Cu 1-Jun-1999 12:00 AM
As InAs 1-Jun-1999 12:00 AM
Zr Zr 1-Jun-1999 12:00 AM
Pb PbF2 1-Jun-1999 12:00 AM

Element	Weight%	Atomic%
C K	47.28	62.38
O K	32.91	32.60
Si K	3.74	2.11
Cu L	1.33	0.33
As L	0.34	0.07
Zr L	14.45	2.51
Pb M	-0.05	0.00
Totals	100.00	

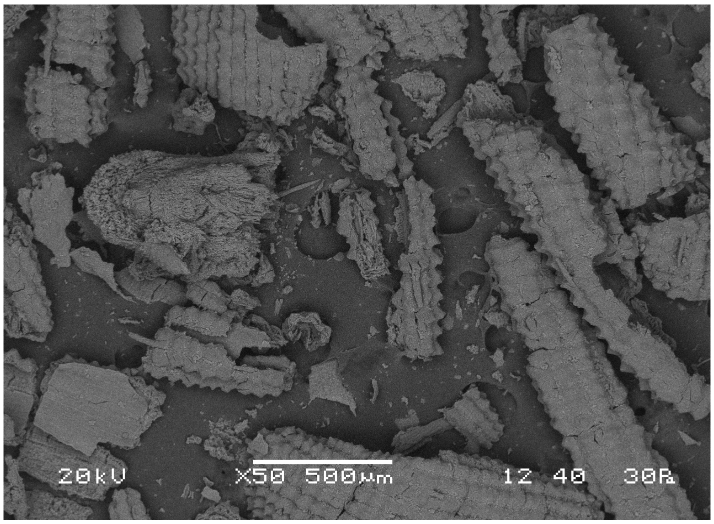
Fig 8(b):X-ray fluorescence spectrum of rice husks.

The results show that grounded rice husk adsorbent material has high carbon and silica contain equal to 47.28% and 3.73% of the total weight of the adsorbent material respectively and all the other metals such as As, Zr, Cu and Pb are present in negligible amount in the adsorbent.

- **Sample-2 (Carbonized Rice Husk):**

Characterisation

The purpose of this work is to improve textural parameters of carbons obtained from rice husk 100g of carbonized rice husks were soaked in 0.6M of citric acid for 2 hours at 20°C. Acid husk slurry is dried overnight at 50°C and the dried husks are heated to 120°C under aerobic conditions. The reacted product is washed repeatedly with distilled water (200ml/g). Finally the cleaned rice husk is oven dried overnight at 100°C (I Nhapi, N Banadda, R Murenzi et.al., Removal of Heavy Metals from Industrial Wastewater Using Rice Husks, The Open Environmental Engineering Journal, 2011, 4: pp 172). The test solutions are prepared by diluting of stock solution containing 100mg/l of Cu (II), Pb (II), Zn (II) to the desired concentrations i.e. 1ppm to 20ppm.



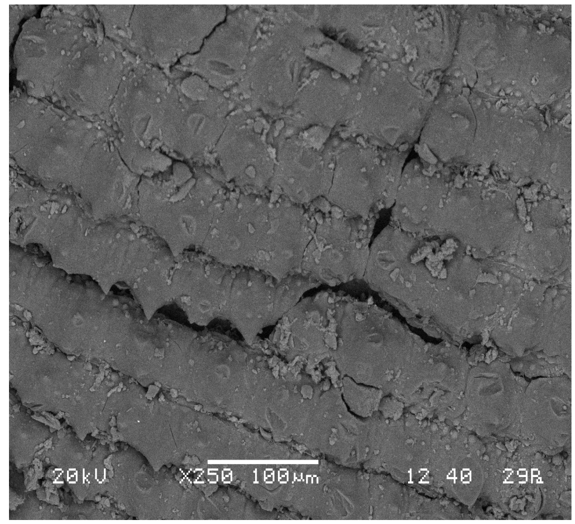


Fig 9: Scanning electron micrograph of rice husks (6355 lm) with (a) 100 and (b) 500 times of magnification.

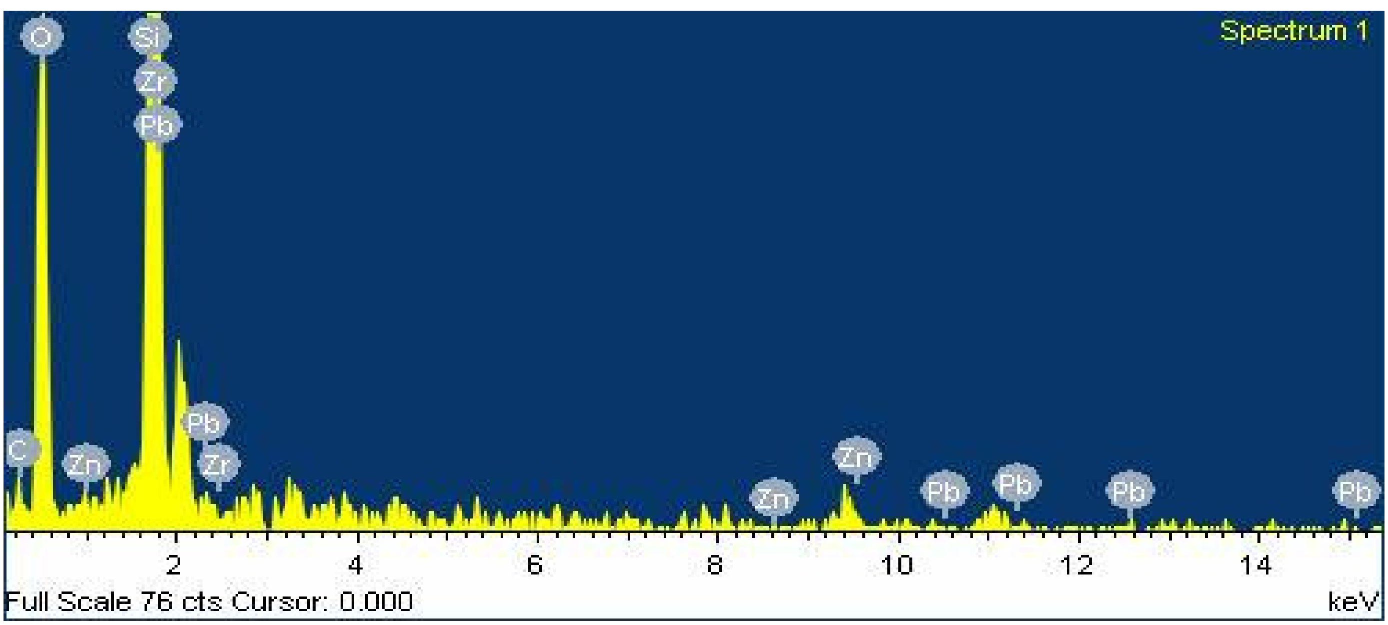
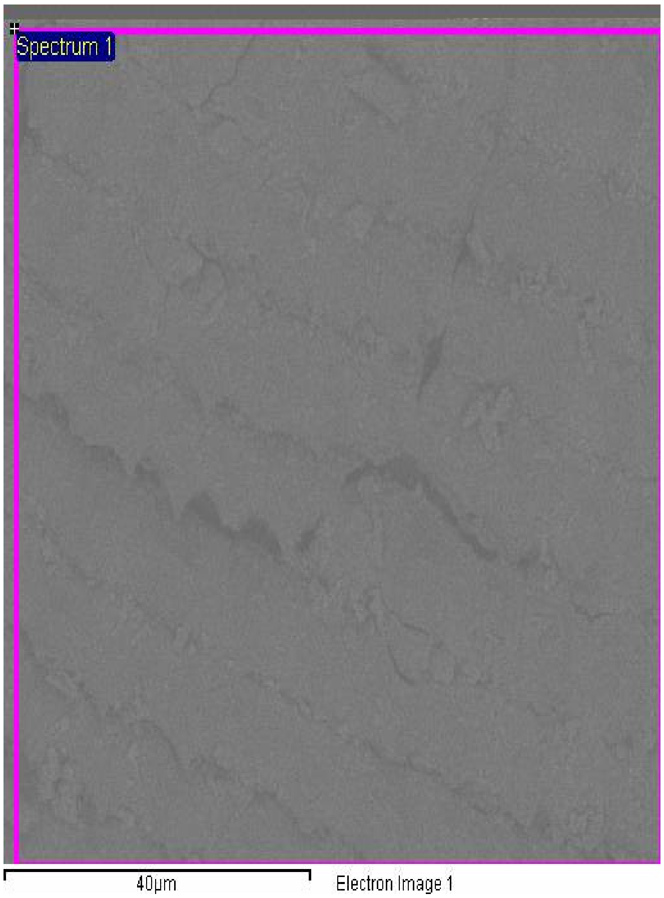


Fig.10(a): X-ray fluorescence spectrum of rice husks.



Spectrum processing :
No peaks omitted

Processing option : All elements analyzed (Normalised)
Number of iterations = 4

Standard :
C CaCO3 1-Jun-1999 12:00 AM
O SiO2 1-Jun-1999 12:00 AM
Si SiO2 1-Jun-1999 12:00 AM
Zn Zn 1-Jun-1999 12:00 AM
Zr Zr 1-Jun-1999 12:00 AM
Pb PbF2 1-Jun-1999 12:00 AM

Element	Weight%	Atomic%
C K	8.52	15.27
O K	36.27	48.78
Si K	43.41	33.26
Zn L	0.47	0.16
Zr L	10.24	2.42
Pb M	1.08	0.11
Totals	100.00	

Fig.10(b): X-ray fluorescence spectrum of rice husks.

The results show that carbonized rice husk adsorbent material (CRH) has high carbon, oxygen and silica contain equal to 8.52%, 36.27%, and 43.41% of the total weight of the adsorbent material respectively and all the other metals such as Zn, and Pb are present in negligible amount in the adsorbent.

CHAPTER- 4

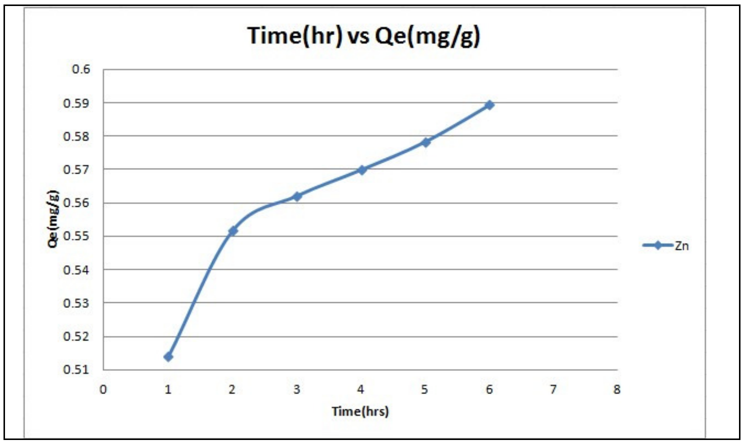
EXPERIMENTAL STUDY AND RESULTS

EXPERIMENTAL STUDIES AND OBSERVATIONS:

Adsorption on grounded rice husk

A series of adsorption experiment were conducted to establish the isotherms for Pb, Cu, Zn adsorption on grounded rice husk. This section presents the results result of the adsorption isotherm of different metal with grounded rice husk.

. Table-1



Time(hr)	Initial conc(mg/l)	Final conc(mg/l)	Qe(mg/g)	% removal
0.5	6.248	1.101	0.514	82.37
1	6.246	0.729	0.5517	88.32
2	6.21	0.589	0.5621	90.51
3	6.162	0.463	0.5699	92.48
5	6.153	0.370	0.5783	93.98
18	6.063	0.170	0.5893	97.19

Figure.11(a) Zn vs time for grounded rice husk.

The amount of metal absorbed per unit mass is calculated as :

$Qe=(Ci-Cf)V/m$

Where Ci and Cf are the initial and final concentration (mg/l),m is mass of adsorbent, V is the volume of the solution (m3).

With increase in time or duration of treatment of effluent the adsorption capacity of the material used shows an increase. After long duration around 48 hours the there will be a negligible amount of heavy metals left in the solution.

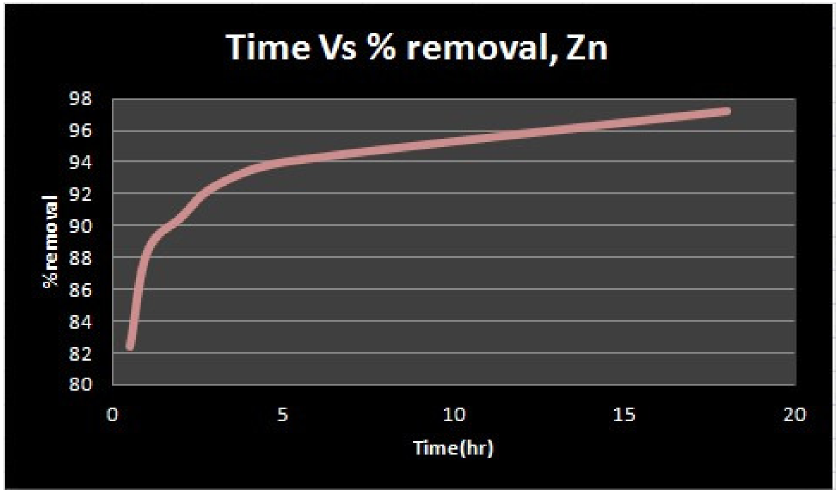


Fig 11(b): Zn vs time for grounded rice husk

With increase in time or duration of treatment of effluent the adsorption capacity of the material used shows an increase. After long duration around 48 hours the there will be a negligible amount of heavy metals left in the solution.

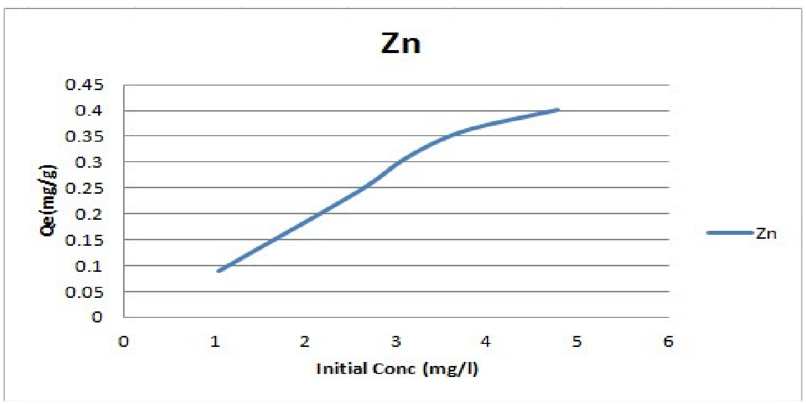


Table-2

Initial conc (mg/l)	Final conc (mg/l)	Qe(mg/g)	% removal
1.033	0.135	0.089	86.93
2.589	0.144	0.2445	94.43
3.079	0.028	0.3051	99.09
3.733	0.14	0.359	96.24
4.778	0.773	0.4005	83.82

Figure.12(a) Effect of initial concentration Zn on the adsorption capacity of grounded rice husks (mass of rice husk: 1.0g; particle size<355 micron).

Increase in initial concentration of heavy metals in the solution shows a gradual increase in the adsorption capacity of adsorbent material.

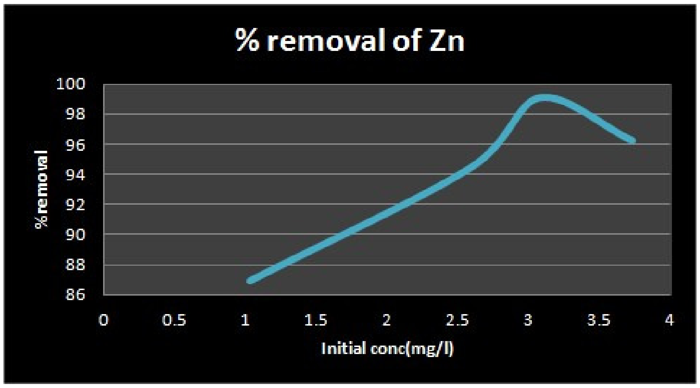
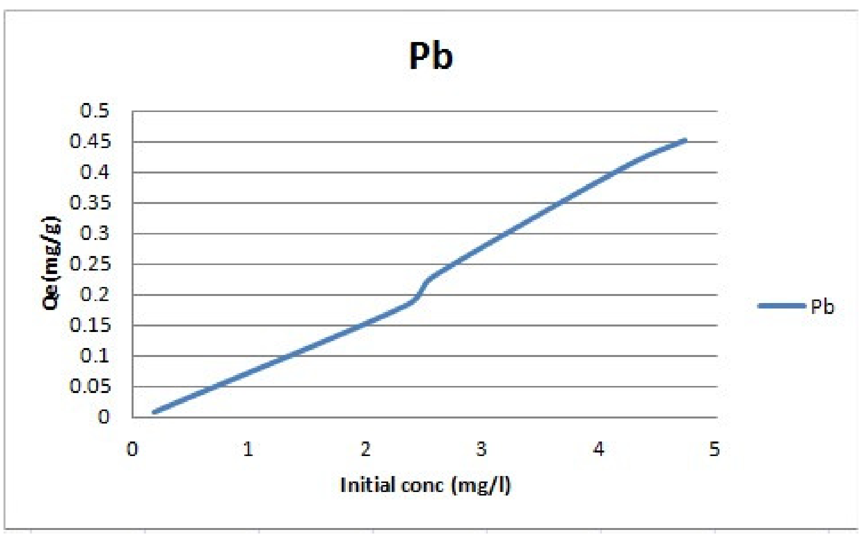


Fig.12(b) graph of initial concentration of Zn vs % removal.

Increase in initial concentration of heavy metals in the solution shows a gradual increase then decrease after the pick in the adsorption capacity of adsorbent material.

Table -3



Initial conc (mg/l)	Final conc (mg/l)	Qe (mg/g)	% removal
0.179	0.093	0.0086	48.044
2.348	0.508	0.184	78.36
2.567	0.267	0.230	89.59
4.212	0.198	0.4095	95.29
4.729	0.117	0.4531	97.52

Figure.13(a) Effect of initial concentration of Pb on the adsorption capacity of grounded rice husks (mass of rice husk: 1.0g; particle size<355 micron).

Increase in initial concentration of heavy metals in the solution shows a gradual increase in the adsorption capacity of adsorbent material.

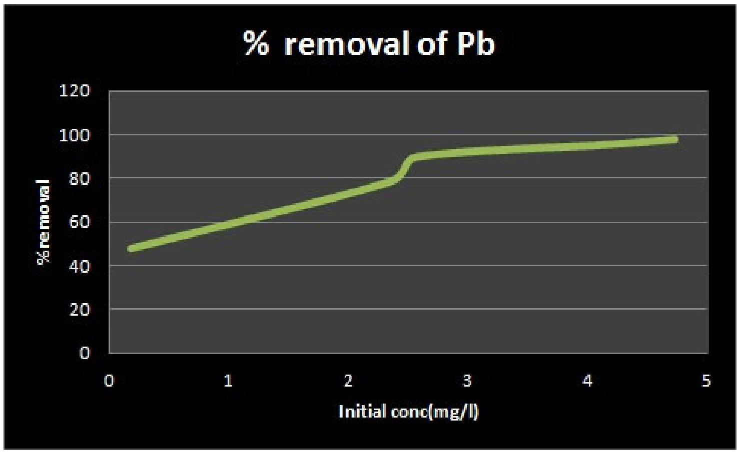
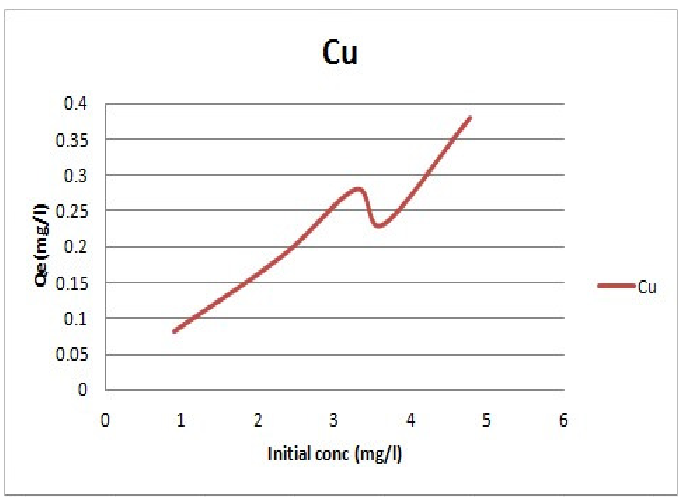


Fig.13(b): graph of initial concentration of Pb vs its % removal.

Increase in initial concentration of heavy metals in the solution shows a gradual increase then decrease after the pick in the adsorption capacity of adsorbent material.

Table-4



Initial conc (mg/l)	Final conc (mg/l)	Qe(mg/g)	% Removal
0.889	0.059	0.083	93.36
2.307	0.420	0.188	81.79
3.271	0.468	0.280	85.69
3.624	1.312	0.231	63.79
4.762	0.969	0.3793	79.65

Figure.14(a) Effect of initial concentration of Cu on the adsorption capacity of grounded rice husks (mass of rice husk: 1.0g; particle size<355 micron)

Increase in initial concentration of heavy metals in the solution shows a gradual increase then decrease after the pick and suddenly increases in the adsorption capacity of adsorbent material.

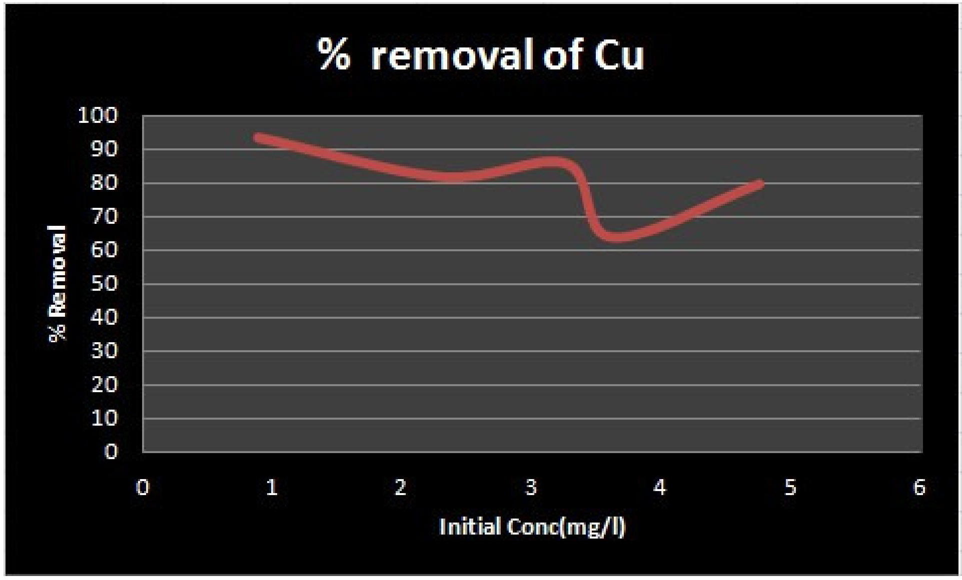
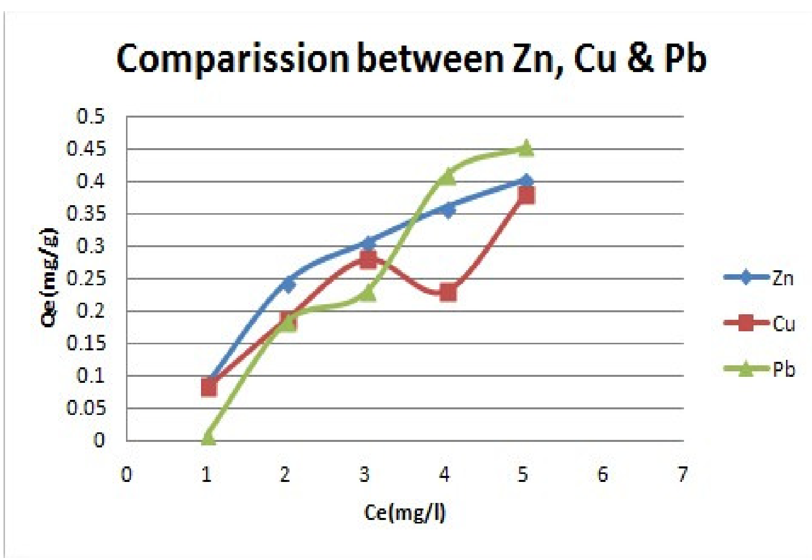


Fig.14(b) graph between initial concentration of Cu & its % removal.

Increase in initial concentration of heavy metals in the solution shows a gradual decrease then sudden increase in the adsorption capacity of adsorbent material.

Table-5



Initial conc(mg/l)	Qe(mg/g) Zn	Qe(mg/g) Cu	Qe(mg/g) Pb
1	0.089	0.083	0.0086
2	0.2445	0.188	0.184
3	0.3051	0.280	0.230
4	0.359	0.2312	0.4095
5	0.4005	0.3793	0.4531

Figure.15(a) Effect of initial concentration of metals Zn, Cu, Pb on the adsorption capacity of grounded rice husks (mass of rice husk: 1.0g; particle size<355 micron)

The graphs shows comparison among the adsorption capacity for removing heavy metals Zn, Cu and Pb. The adsorption capacity of the material decreases in order Pb>Zn>Cu.

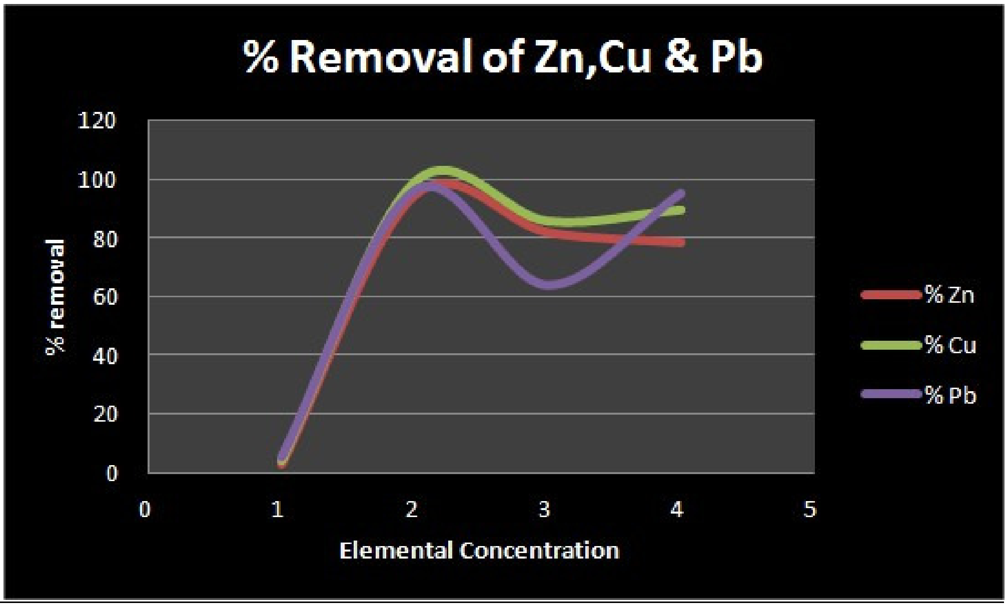


Figure.15(b) Graph between initial concentration of metals of the Zn, Cu, Pb and their respective %removal by grounded rice husk.

The graphs show comparison among the adsorption capacity for removing heavy metals Zn, Cu and Pb. The adsorption capacity of the material decreases in order Cu>Zn>Pb.

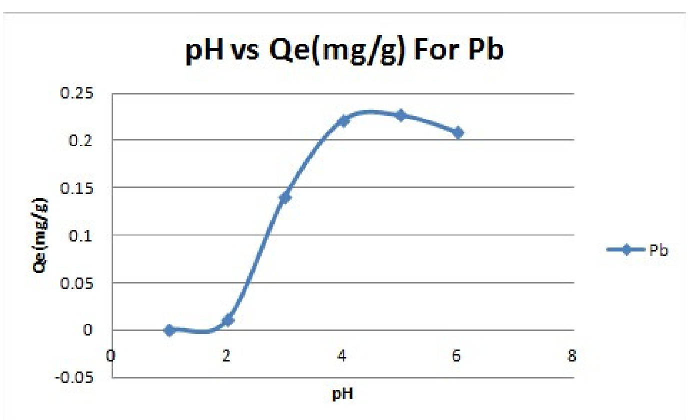


Table-6

PH	Initial conc (mg/l)	Final conc (mg/l)	Qe(mg/g)
2	0.891	0.677	0.0107
3	0.347	0.0646	0.1412
4	0.466	0.02282	0.2216
5	0.636	0.1824	0.2268
6	0.458	0.0406	0.2087

Figure.16 Effect of pH on removal of the Pb by the rice husk (mass of rice husk: 2.0g; particle size<355 micron; 5 ppm of Pb for each)

The graph shows the gradual increase then decrease in the adsorption capacity of the adsorbent material with increase in pH of the solution.

Adsorption on carbonized rice husk

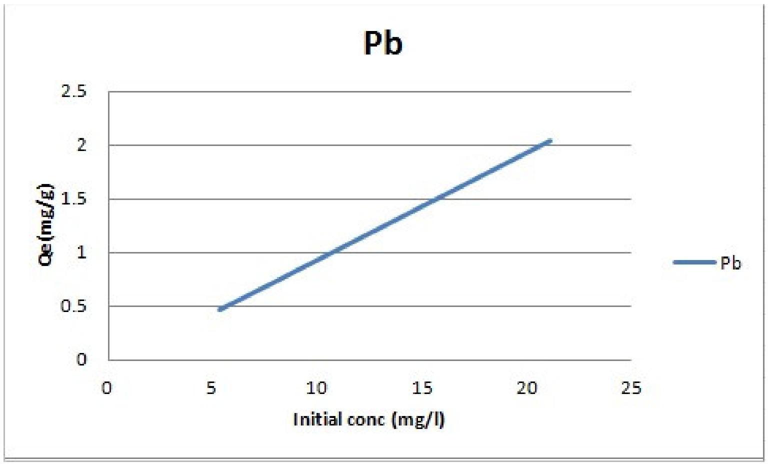


Table-7

Initial conc (mg/l)	Final conc (mg/l)	Qe(mg/g)	% removal
5.3	0.68	0.462	87.16
6.9	0.7	0.62	89.85
7.92	0.72	0.72	90.78
12.23	0.73	1.15	94.03
21.15	0.75	2.04	96.45

Figure.17(a) Effect of initial concentration of Pb on the adsorption capacity of carbonized rice husks (mass of rice husk: 1.0g).

The graph shows the gradual increase in the adsorption capacity of the material with increase in initial concentration of Pb.

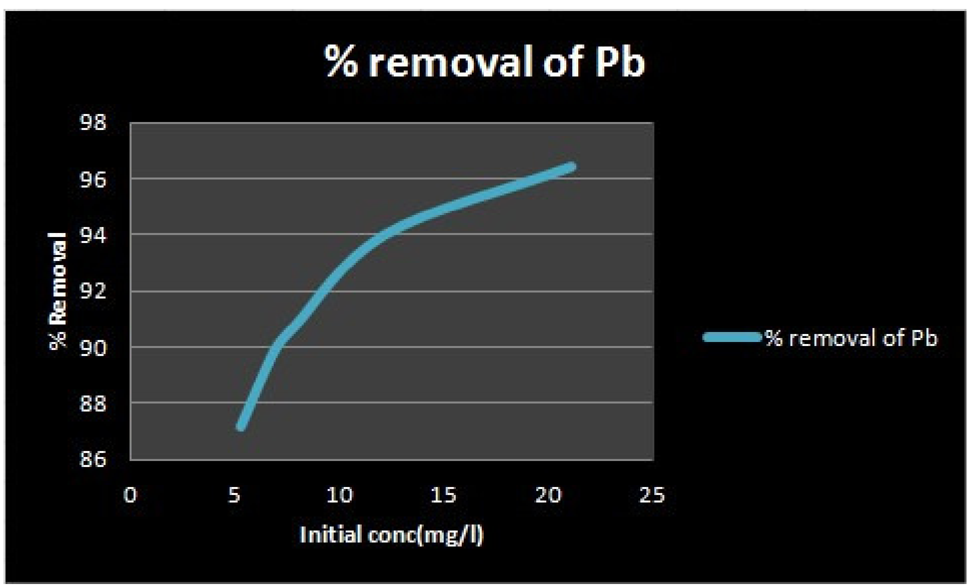
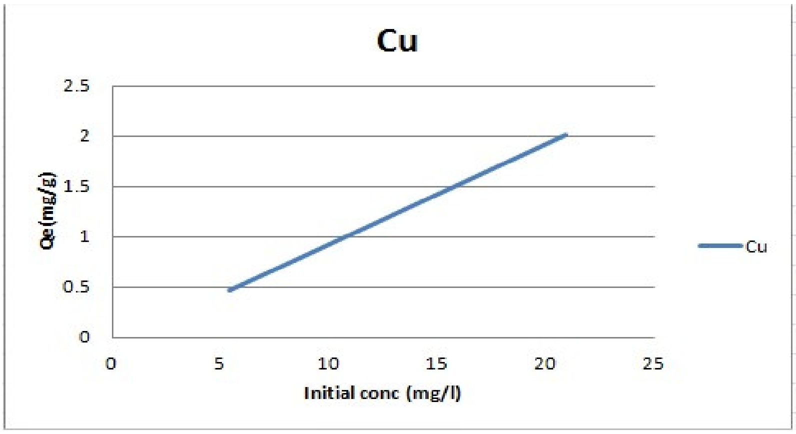


Fig.17(b): Graph of initial concentration of Pb vs its % removal in carbonized rice husk.

The graph shows the gradual increase in the adsorption capacity of the material with increase in initial concentration of Pb.

Table-8



Initial conc (mg/l)	Final conc (mg/l)	Qe(mg/g)	% removal
5.43	0.73	0.47	86.55
6.87	0.74	0.613	89.22
8.05	0.75	0.73	90.68
12.76	0.76	1.20	94.04
20.89	0.77	2.012	96.31

Figure.18 (a) Effect of initial concentration of Cu on the adsorption capacity of carbonized rice husks (mass of rice husk: 1.0g)

The graph shows the gradual increase in the adsorption capacity of the material with increase in initial concentration of Cu.

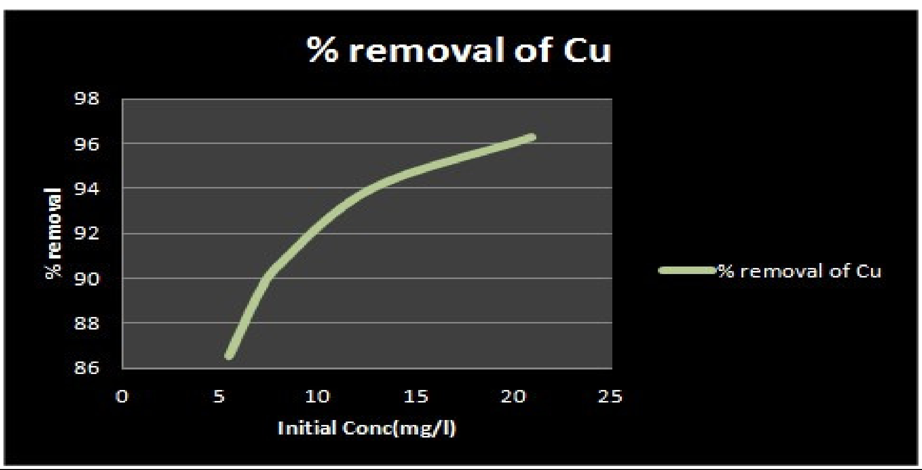


Fig.18(b) graph of initial concentration of Cu vs its % removal in carbonized rice husk.

The graph shows the gradual increase in the adsorption capacity of the material with increase in initial concentration of Cu.

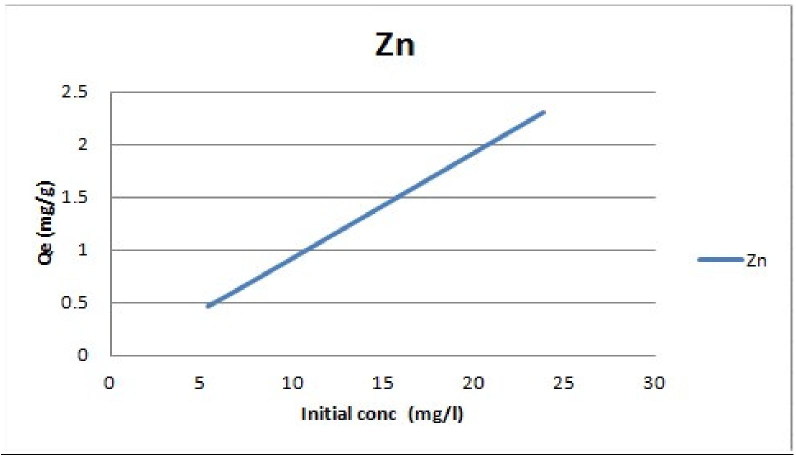


Table-9

Initial conc (mg/l)	Final conc (mg/l)	Qe(mg/g)	% removal
5.38	0.65	0.473	87.91
6.93	0.72	0.621	89.61
7.89	0.74	0.715	90.62
14.02	0.78	1.324	94.43
23.85	0.80	2.305	96.64

Figure.19 (a) Effect of initial concentration of Zn on the adsorption capacity of carbonized rice husks (mass of rice husk: 1.0g).

The graph shows the gradual increase in the adsorption capacity of the material with increase in initial concentration of Zn.

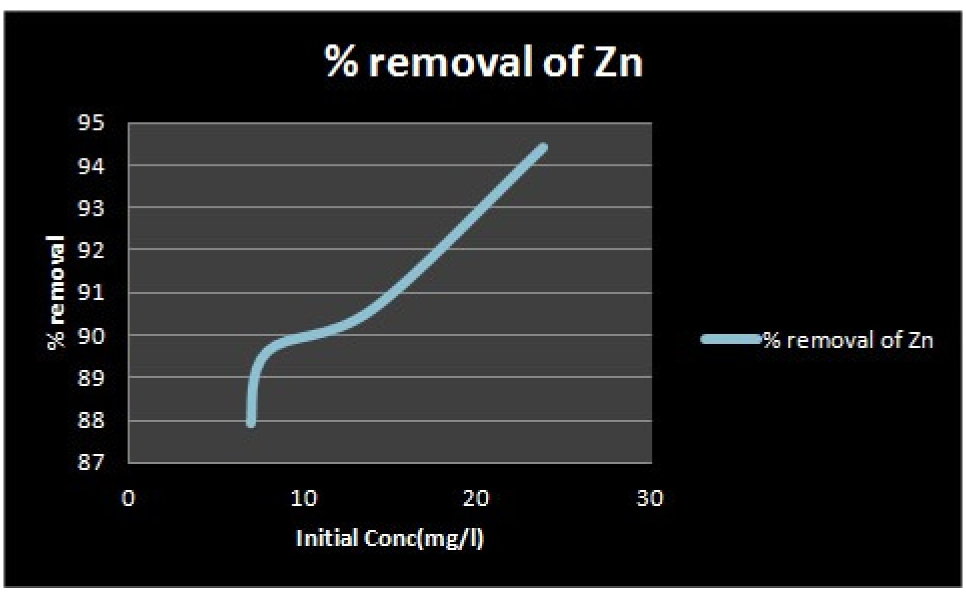
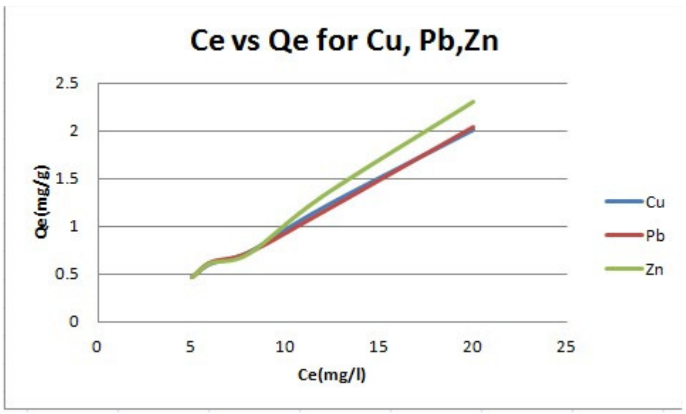


Fig.19(b) graph of initial concentration of Zn vs its % removal in carbonized rice husk.

The graph shows the gradual increase in the adsorption capacity of the material with increase in initial concentration of Zn.



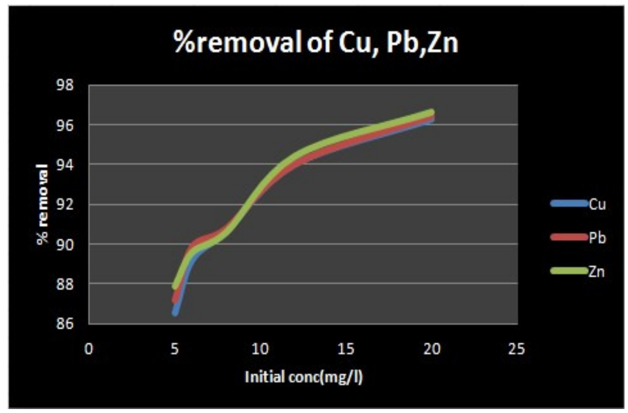


Fig.20.(a) & (b): Comparison graph among Cu, Pb & Zn.

Table-10

Initial conc(mg/l)	% removal	% removal	% removal
5	87.16	86.55	87.91
7	89.85	89.22	89.61
9	90.78	90.68	90.62
14	94.03	94.04	94.43
20	96.45	96.31	96.64

The adsorption capacity of the material decreases in order of Zn>Pb>Cu. The adsorption capacity increases with increase in initial concentration of heavy metal present in the solution and is true for each metal.

CHAPTER-5

CONCLUSION

CONCLUSIONS

The chemical characterization obtained from the analysis of scanning electron microscope of rice husk shows carbon and silica content in the grounded rice husk as 47.28% and 3.73%, respectively. The results show carbon, oxygen and silica content in carbonized rice husk as 8.52%, 36.27% and 43.41%, respectively.

After the chemical characterization, the material was used for removing Zn, Cu and Pb from laboratory prepared effluents. Under certain optimized conditions such as constant temperature of 40 degree centigrade, speed of stirring action as 250rpm for 24 hours, 1 g of adsorbent per each 100ml solution of heavy metals, the results obtained are summarized as:

- The adsorption capacity of grounded rice husk decreases in order Pb > Zn > Cu.
- The adsorption capacity of grounded rice husk for removing metals increases with increasing pH of the solution.
- Longer duration of time gives high values of adsorption capacity.
- High initial concentration of metals mostly gives high values of adsorption capacity.
- The adsorption capacity of carbonized rice husk decreases in order of Zn > P b > Cu.
- Carbonated rice husk and grounded rice husk demonstrated higher potential to remove relatively all selected heavy metals.
- After 48 hours it will leave a negligible amount of metals in the treated water.
- The efficiency of both the adsorbents in the removal of desired heavy metals was 95-100%, or nearly 100%.
- The results show the removal efficiency of grounded rice husk for Zn, Pb and Cu as 99.09%, 97.52% and 93.36 %, respectively. The removal efficiency of carbonized rice husk for Pb, Cu and Zn is found to be 96.45%, 96.31% and 96.64%, respectively. Increase in the duration of stirring action the removal efficiency of the adsorbent material increases. As per the observation, removal of Zn from 5ppm solution of Zn for 0.5,1,2,3,5,18 hours are 82.37%, 88.32%,90.51%,92.48%,93.98% and 97.19%, respectively.

Chapter-6

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